FABRICATION OF GENESIS SAMPLE SIMULANTS USING PLASMA SOURCE ION IMPLANTATION (PSII).

K. R. Kuhlman, California Institute of Technology, Jet Propulsion Laboratory, MS 302-231, Pasadena, CA, 91109; kkuhlman@jpl.nasa.gov.

Introduction: The Genesis mission addresses questions about the materials and processes involved in the origins of the solar system by providing precise knowledge of solar isotopic and elemental compositions, a cornerstone data set around which theories for materials, processes, events and time scales in the solar nebula are built, and from which theories about the evolution of planets begin. Genesis measures solar composition by collecting solar wind implanted in various passive collector materials for analysis in terrestrial laboratories. Genesis has also implemented an active concentrator target, important for the analysis of oxygen isotopes in the solar wind.

Implanted Solar Wind Depth Profiles: Solar wind ions have ranges in materials on the order of 10 to a few hundred nanometers. In the case of $^{4}He^{+}$ in minerals, the mean range is about 25 nm [1]. While secondary ion mass spectroscopy (SIMS) and stepwise heating provide valuable data on total elemental abundances and isotopic ratios, depth profiles are needed to characterize elemental and isotopic fractionations, a scientific goal of Genesis. Depth profiles at the scale of tens of nanometers are extremely difficult to measure at present and are typically simulated using the code, the Stopping and Range of Ions in Matter (SRIM) [1]. Radiation damage and diffusion effects complicate the interpretation of depth profile.

Solar Wind Simulation Using Plasma Source Ion Implantation: In order to validate existing sample preparation and analysis techniques without destroying the precious Genesis samples, it is desirable to test these techniques using samples that can be fabricated at will in the laboratory. Linear particle accelerators cannot efficiently perform low energy implantations of light elements such as those found in the solar wind. These accelerators also require focusing using magnetic fields that can cause the ions to be implanted non-normal to the surface. Plasma Source Ion Implantation (PSII) however, is capable of implanting these elements at solar wind energies, approximately 1 kV/q/amu [2].

Plasma source ion implantation (PSII) is a non-line of sight technique for the surface modification of materials [3]. The target -- in this case a silicon wafer with wafered samples lying on top -- is placed in a 1 m^3 chamber which is evacuated to a base pressure of about 10^{-6} torr. Gas of the species to be implanted is allowed to flow through the chamber at a pressure of several millitorr. A plasma is generated using tungsten filaments to ionize the gas by energetic primary electron impact. Other ways of generating a plasma for higher energy implantations include radiofrequency (RF) and glow discharge methods.

A series of negative high voltage pulses are applied to the target, and the resulting electric field accelerates the ions in the plasma to high energies normal to the surface of the target (Figure 1) [4]. In the case of a wafer, significant asymmetries can occur at the edges where the electric field is changing rapidly. The terrestrial mineral samples were placed away from the edges of a large wafer in order to achieve a uniform implantation.

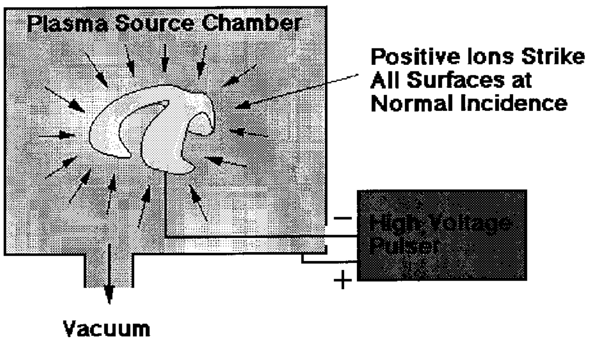

Figure 1. Schematic diagram of the Plasma Source Ion Implantation (PSII) process (showing the implantation of an artificial knee component) [4].

Harris-Kuhlman (1998) demonstrated that PSII can be used to simulate the implantation of hydrogen and helium isotopes into terrestrial minerals with results similar to those from the Apollo 11 regolith samples (Figure 2) [2,5,6].

Benefits to the Genesis Community: The main benefit of using PSII to fabricate Genesis sample simulants is that the samples will be very similar to those to be returned by the Genesis mission in 2004. These samples are needed by investigators to validate and improve sample preparation and analysis techniques such as secondary ion mass spectroscopy (SIMS), gas source mass spectrometry (GSMS), resonance ionization mass spectrometry (RIMS), and radiochemical neutron activation analysis (RNAA) [7]. Other techniques such as atom probe field ion microscopy [8] may be uniquely capable of measuring the depth profiles of implanted solar wind species and will require simulants to develop methods for sample preparation and calibration.

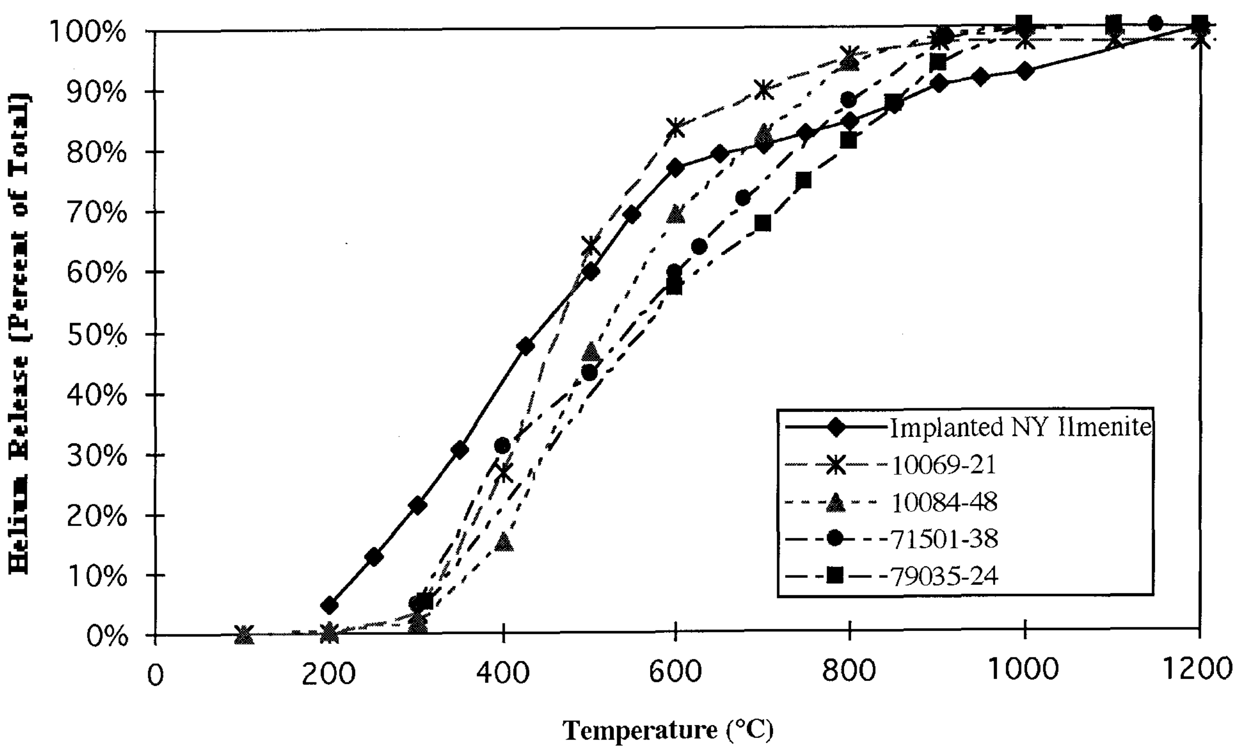

Figure 2. Release data of helium from the implanted New York ilmenite and samples of rocks and regolith from Apollo 11 [5] and Apollo 17 [6]. Annealing steps of 50°C and 30 minutes were used for the implanted terrestrial sample while steps of approximately 100°C and 1 hour were used for the Apollo samples.

Approach: Sample wafers identical to the particle collectors on Genesis will be procured and prepared at JPL with the same coatings as the flight collectors. These wafers will then be implanted with the various elemental and isotopic ratios found in the solar wind with energies of 1 kV/q/amu using PSII at the University of Wisconsin – Madison. The total fluences of these implantations will be the same as those expected during the various phases of the Genesis mission [7]. Isotopes of the noble gases and other elements such as Li, B, C, N, O, Mg, Si, S, and Fe will be implanted according to measured isotope ratios and fluxes measured by the Apollo 16 Solar wind composition (SWC) experiment [9], and the Ulysses, WIND and SOHO spacecraft. The Genesis concentrator target will be simulated with and without hydrogen and helium to demonstrate the effect of enhanced fluences due to the concentrator. Finally, higher energy particles will be implanted to simulate solar flare interactions with Genesis. The high energy implantations can be tailored to match the fluence and energy spectra of the flares based on the measurements from the Genesis solar wind monitor which measures the density, velocity, temperature, and anisotropy of the protons and alpha particles as a function of time. The samples will then be divided and made available to the Genesis investigators and the international scientific community for use in developing and refining sample preparation and analysis techniques.

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